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I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PR 0158 for a patent by SIGNAL DATA SYSTEMS PTY LTD filed on 15 September 2000.

I further certify that pursuant to the provisions of Section 38(1) of the Patents Act 1990 a complete specification was filed on 04 September 2001 and it is an associated application to Provisional Application No. PR 0158 and has been allocated No. 65629/01.



WITNESS my hand this
Fourteenth day of February 2002

J Billingsley

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ORIGINAL
AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Invention Title: "Method For Communicating Between A First Station And A
Second Station, And A Controller And Remote Station"

The invention is described in the following statement:

"Method For Communicating Between A First Station And A Second Station, And A Controller And Remote Station"

Field of the Invention

This invention relates to a method for communicating between a first station and
5 a second station, and to a controller and remote station using the communication
method. The invention is particularly useful in the field of irrigation systems,
however the invention may also be applied to other fields.

Background Art

In many areas of the world the availability of water to maintain the natural growth
10 of plants is either insufficient or unreliable, especially if the plants are not native
to the area. For centuries this problem has been overcome by the development
of irrigation systems where water is transferred from a local available source
such as a river, dam or bore and used to artificially irrigate the plants.

The twentieth century has seen the further development of irrigation systems to
15 the level of total computerised automation. This has resulted in many areas of
the world having large tracts of previously unusable arid land that are now
capable of producing crops of all types.

A typical irrigation system comprises of a network of underground pipes along
which water is pumped. Selected valves at strategic points on this network, when
20 activated, release water to local distribution points such as sprinklers or drippers.
The method of activating these valves may vary, but typically they would be
triggered by electrical, mechanical, hydraulic or manual means.

The most common electrical device comprises of an electro-mechanical
solenoid. An activating current causes the device to move a spring-loaded
25 plunger, allowing the valve to open due to the water pressure in the irrigation
pipes. When this current is either removed or possibly reversed, the plunger
returns to its original state thus allowing the valve to close.

The solenoids are activated, either directly or remotely, by an electrical or electronic control systems such as irrigation controllers, programmable logic controllers (PLC's) or even manual switches.

- 5 The most common form of irrigation solenoid is activated on application of a voltage of 24 volts AC. Other solenoids activate on a range of different voltages from 6 to 48 volts, either being AC or DC. In order to minimise power consumption, latching solenoids are available which enable on the receipt of a voltage pulse of one polarity and disable when a voltage pulse of the reverse polarity is received.
- 10 The typical means of transferring the current required to activate these solenoids are a pair of cables running for distances of up to two kilometres from the controlling system. The limitations on this distance are dependent on the resistance of the cable such that sufficient power is available to activate the solenoid for the required time.
- 15 Commercial irrigation sites such as farms, parks or golf courses can cover large areas, consequently the length of cabling required to service all the solenoids may run to many kilometres. Currently there are two main techniques in use to distribute power to the solenoids, referred to as 'Direct Connection' and 'Two-Wire'. A brief description of these techniques follows.
- 20 Direct connection is the older or more traditional method, which is to supply power directly from an activating relay (or similar electronic device) within a control system by a directly connected pair of cables. It should be noted that the word 'pair' only refers to the connection point at the solenoid, as the typical wiring layout of such an installation is normally a matrix of single cables with the 'pairs'
- 25 only occurring at the required solenoid junction locations.

Two-wire systems provide both power and activating commands along a single network. This network is generally consists of a true 'pair' of cables and each solenoid within the network is activated by a corresponding decoder connected between it and the network. A master irrigation controller powers and issues

commands to the decoders via the pairs of cables. The format of the command communications depends on the manufacturer's preference. Many existing systems utilise tone or DTMF (Telephone-type tones) signals superimposed on the powering voltage. Normally (and preferably) the network is wired in a 'point
5 to point' configuration between the master irrigation controller and the decoders.

Most control systems activate solenoids by applying a 24v AC 50 Hz RMS power signal to the solenoid. Although this technique appears both obvious and simple, a number of problems and limitations do occur.

A typical solenoid used requires around 3 watts at 24v to hold in, resulting in a
10 holding current of around 300 mA. When the solenoid is activated, the inrush current can be double (or more) the holding current. Under certain site conditions, the inrush current can also increase beyond this level by quite a considerable degree.

One example of inrush current increase is where a solenoid plunger was clogged
15 with sediment or sand. On activation, if the force of the solenoid were not sufficient to move the clogged plunger, the plunger would vibrate violently at the waveform frequency and could take a number of seconds to activate. In this case the instantaneous inrush currents could exceed four or five times the stated holding current. If this solenoid was being activated some distance from the
20 voltage source (the irrigation controller) or if other solenoids were also being activated which used common cabling runs, the resistance of the wire could cause the following scenarios to occur:

- The solenoid would not activate.
- The voltage drop and solenoid-induced interference at the decoder could
25 be sufficient to cause the decoder electronics to reset, fail, or run unreliably.
- If the irrigation controller is equipped with current sensing, it could shut down the section being irrigated and skip to the next section.

- The current drawn (under worst cases) could cause a fuse to blow or trip at the irrigation controller. In this case irrigation could be suspended or cancelled.

Disregarding back-EMF voltages and other considerations, it may generally be
5 assumed that when a solenoid is activated by an AC sinusoidal voltage the maximum amount of current flow occurs at the 90 and 270 degree points of the waveform, with the zero cross (no current drawn) occurring at the 0 and 180 degree points.

As more solenoids are activated simultaneously, the current draw will
10 consequently increase. If two solenoids are activated with similar characteristics then the current draw will almost double. The difference will depend on the resistance and length of the supplying cable. Currently most two-wire systems start to become unreliable when operating multiple solenoids over distances exceeding one or two kilometres (utilising standard irrigation cabling). Some
15 manufactures overcome this problem by specifying thicker or custom manufactured cabling, which greatly increases the cost of the installation.

Disclosure of the Invention

Throughout the specification, unless the context requires otherwise, the word
"comprise" or variations such as "comprises" or "comprising", will be understood
20 to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

In accordance with a first aspect of this invention, there is provided a method for communicating between a first station and a second station over a distribution medium, comprising the steps of:

25 The first station sending an alternating power signal over the distribution medium, the alternating power signal comprising a plurality of communication symbols;

The second station receiving the alternating power signal and determining therefrom the communication symbols;

The second station syncing current from the alternating power signal in a sequence corresponding to at least one further communication symbol;

- 5 The first station determining current draw in the alternating power signal to recover the further communication symbol.

Preferably, the alternating power signal has substantially equally proportions of positive and negative components, averaged over time.

Preferably, the alternating power signal has a substantially square wave-form.

- 10 Preferably, the distribution medium comprises a pair of wires.

Preferably, the second station is arranged to sink current during a positive portion and a negative portion of the alternating power signal.

- 15 Preferably, the second station is arranged to sink current during the positive portion of the alternating power signal in a sequence corresponding to at least one further communication symbol, and to repeat said current sync in the negative portion of the alternating power signal.

Preferably, each second station derives its power from the alternating power signal.

- 20 Preferably, the second station is arranged to sink current during a prescribed section of the alternating power signal.

In one arrangement, the prescribed section is substantially centrally located in each positive portion and negative portion of the alternating power signal.

In an alternative arrangement, the prescribed section is adjacent each rising edge and falling edge of the alternating power signal.

In a preferred form of the arrangement, the second station is arranged not to derive power from the alternating power signal during the prescribed section other than the current sink.

In one arrangement, the communications symbols comprise '1', '0' and 'idle'.

- 5 In a preferred form of the arrangement, the communications symbols further comprise 'sync'.

In a preferred form of the arrangement, the '0' and 'idle' symbols are the same.

- In a preferred form of the arrangement, the '0' symbol is represented by equal portions of positive and negative components in the alternating power signal, and
10 the '1' symbol is represented by unequal portions of positive and negative components in the alternating power signal.

In a preferred form of the arrangement, the proportion of positive and negative components in the alternating power signal representing a '1' symbol is alternated each time a '1' symbol is sent.

- 15 Preferably, the plurality of communication symbols form a stream, selected from one of:

A command stream comprising a sync pulse, an instruction byte, and station instructions;

An idle stream comprising a sync pulse, and a plurality of idle symbols;

- 20 A instruction stream, comprising a sync pulse, an instruction byte, a station address, and station data.

Preferably, there are a plurality of second stations, each second station having an address, each second station responsive to station instruction/data at a position in the command stream corresponding to their address.

Each second station is arranged to sink current during an idle pulse at a position in the command stream corresponding to their address.

In accordance with a second aspect of this invention, there is provided an apparatus for communicating with at least one second station over a distribution
5 medium, comprising:

Means for providing an alternating power signal over the distribution medium, the alternating power signal comprising a plurality of communication symbols; and

10 Control means arranged determine current draw in the alternating power signal to recover at least one further communication symbol from a second station.

Preferably, the means for providing an alternating power signal comprises a power switching circuit connected to and operating under control of the control means, the power switching circuit operable to provide an alternating power
15 signal over said distribution medium.

Preferably, the alternating power signal has substantially equally proportions of positive and negative components, averaged over time.

Preferably, the alternating power signal has a substantially square wave-form.

Preferably, the distribution medium comprises a pair of wires.

20 In one arrangement, the communications symbols comprise '1', '0' and 'idle'.

In a preferred form of the arrangement, the communications symbols further comprise 'sync'.

In a preferred form of the arrangement, the '0' and 'idle' symbols are the same.

In a preferred form of the arrangement, the '0' symbol is represented by equal portions of positive and negative components in the alternating power signal, and the '1' symbol is represented by unequal portions of positive and negative components in the alternating power signal.

- 5 In a preferred form of the arrangement, the proportion of positive and negative components in the alternating power signal representing a '1' symbol is alternated each time a '1' symbol is sent.

Preferably, the control means is arranged to control the power switching circuit to form the alternating power signal from a plurality of communication symbols
10 forming a stream, selected from one of:

A command stream comprising a sync pulse, an instruction byte, and station instructions;

An idle stream comprising a sync pulse, and a plurality of idle symbols;

A instruction stream, comprising a sync pulse, an instruction byte, a station
15 address, and station data.

Preferably, the control means is arranged to determine current draw during a prescribed section of the alternating power signal.

In one arrangement, the prescribed section is substantially centrally located in each positive portion and negative portion of the alternating power signal.

- 20 In an alternative arrangement, the prescribed section is adjacent each rising edge and falling edge of the alternating power signal. In accordance with a third aspect of this invention, there is provided an apparatus for communicating with a first station over a distribution medium, comprising:

Means for receiving an alternating power signal comprising a plurality of communication symbols over the distribution medium, and for recovering the communication symbols therefrom; and

- 5 Control means arranged to draw current from the alternating power signal in a sequence corresponding to at least one further communication symbol.

In one arrangement, the communications symbols comprise '1', '0' and 'idle'.

In a preferred form of the arrangement, the communications symbols further comprise 'sync'.

- 10 In a preferred form of the arrangement, the '0' and 'idle' symbols are the same.

In a preferred form of the arrangement, the '0' symbol is represented by equal portions of positive and negative components in the alternating power signal, and the '1' symbol is represented by unequal portions of positive and negative components in the alternating power signal.

- 15 In a preferred form of the arrangement, the proportion of positive and negative components in the alternating power signal representing a '1' symbol is alternated each time a '1' symbol is sent.

Preferably, the control means is arranged to sink current during a positive portion and a negative portion of the alternating power signal.

- 20 Preferably, the control means is arranged to sink current during the positive portion of the alternating power signal in a sequence corresponding to at least one further communication symbol, and to repeat said current sink in the negative portion of the alternating power signal.

- 25 Preferably, the second station is arranged to sink current during a prescribed section of the alternating power signal.

In one arrangement, the prescribed section is substantially centrally located in each positive portion and negative portion of the alternating power signal.

In an alternative arrangement, the prescribed section is adjacent each rising edge and falling edge of the alternating power signal.

- 5 In a preferred form of this arrangement, the second station is arranged not to derive power from the alternating power signal during the prescribed section other than the current sink.

Brief Description of the Drawings

- 10 Two embodiments of this invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a system of a controller and remote stations in accordance with the preferred embodiment of this invention;

Figure 2 shows a block diagram of the controller shown in Figure 1;

Figure 3 is a block diagram of a remote station shown in Figure 1;

- 15 Figure 4a shows wave forms of a "synchronisation" pulse, a "zero" pulse and an "one" pulse used by the controller in Figure 1; and

Figure 4b shows an example alternating power signal from the controller.

Best Mode(s) for Carrying out the Invention

- 20 The embodiment will be described with reference to a controller and remote stations used in an irrigation system, however it should be appreciated that the invention may well have application in other areas.

Figure 1 shows the system 10 comprising a controller 12 and eight remote stations 14a – 14 h.

The remote stations 14a – 14h are connected to the controller 12 by a pair of wires 16. The remote stations 14a – 14h are connected in parallel across the pair of wires 16.

5 In the embodiment, the remote stations 14a – 14h comprise a decoder 18 and a solenoid 20 which, when activated, irrigates an area of land. Although the embodiment is described with reference to a single pair of wires 16 and eight remote stations, it should be appreciated that the number of remote stations will vary according to the area of land to be irrigated.

10 Figure 2 shows a block diagram of the controller 12, comprising a microprocessor and associated memory 22, a power circuit 24 connected to the microprocessor 22 and an interface 26 connected to the microprocessor 22.

15 The power circuit 24 comprises an H-Bridge circuit in the embodiment formed from four power MOSFETs 28a – 28d. The power MOSFETs 28a and 28b are connected in series between a power rail 30 and a second rail 32 that is connected to ground via a resistor 25. The power MOSFETs 28c and 28d are also connected in series between the power rail 30 and the second rail 32, in parallel with the power MOSFETs 28a and 28b. A pair of terminals 34 are provided, one connected between the power MOSFETs 28a and 28b, and one connected between the power MOSFETs 28c and 28d, as shown in Figure 2.

20 The terminals 34 are connected to the pair of wires 16. By activating the power MOSFETs 28a and 28d, and then alternately activating the power MOSFETs 28c and 28b, and alternating power signal is provided on the pair of wires 16. The power MOSFETs 28a – 28d are activated under control of the microprocessor 22 via appropriate bias circuitry 36. The interface 26 is an RS-232 serial interface in

25 the embodiment to allow the microprocessor 22 to receive instructions from an external source if desired.

The controller 12 further comprises a symbol recovery circuit 27 comprising an amplifier 29, a filter 31 and hysteresis circuit 33. The input of the amplifier 29 is connected to the second rail 32, and accordingly the voltage at the input of the

30 amplifier 29 is equal to that across the resistor 25, which is proportional to the

current being drawn by the power circuit 24. The output of the amplifier is connected to the filter 31, the output of which is connected to the hysteresis circuit 33. The hysteresis circuit 33 acts to disconnect step tunes as in the current drawn from the power circuit 24. The output of the hysteresis circuit is
5 input to the microprocessor 22.

The symbol recovery circuit 27 detects communication symbols imposed on the alternating power signal by remote stations as will be described in further detail below.

Figure 3 is a block diagram of one of the remote stations 14a – 14h. Each of the
10 remote stations 14a – 14h are of the same general form as shown in figure 3.

Each remote station comprises a decoder 18 formed from a power and zero crossing circuit 38, a microprocessor and associated memory 40 and a power generation circuit 42.

The power and zero crossing circuit 38 is connected to the pair of wires 16. The
15 power and zero crossing circuit 38 produces a local power supply from the alternating power signal on the pair of wires 16 for use by the microprocessor 40 and the power generation circuit 42. The power and zero crossing circuit 38 also produces a signal indicating when the alternating power signal changes polarity, which is input to the microprocessor 40.

20 The power generation circuit 42 operates under control of the microprocessor 40 to provide power to the solenoid 20 in accordance with instructions received from the controller 12 as will described below. The power generation circuit 42 is of the same form as the power circuit 24 of the controller 12.

The decoder 18 further comprises a current drawing circuit that is connected to
25 the pair of wires 16 and to the microprocessor 40. The current drawing circuit operates under instruction from the microprocessor 40 to draw a predetermined amount of current from the alternating power signal. In the embodiment, the current drawing circuit 39 is arranged to draw 100 milliamps of current. This

allows the decoder 18 to communicate with the controller 12 as will be described in further detail below.

The controller 12 communicates with the decoders 18 in each remote station 14a – 14h by composing the alternating power signal from combinations of communication symbols. The examples of the communication symbols used in the embodiment are shown in figure 4a.

Figure 4a shows examples of a synchronisation pulse or synch pulse, a “zero” (or idle) pulse and a “one” pulse. In this embodiment, the synchronisation pulse is twice the width of the zero and one pulses.

- 10 The microprocessor 22 of the controller 12 operates to control the power circuit 24 to produce the alternating power signal formed from communication symbols to form command streams of the communication symbols. In the embodiment, the microprocessor 22 is arranged to produce one of three types of streams, which are shown in figures 4b – 4d.
- 15 The first type of stream, referred to a command stream, comprises a sync pulse, followed by an instruction byte, followed by eight activation pulses, one for each of the remote stations 14a – 14h. In other embodiments, the number of activation pulses following the instruction byte would be varied according to the number of remote stations, or alternatively a fixed number greater than the number of remote stations may be used, such as 100.

In the command stream shown in figure 4b, the instruction byte determines the nature of the instruction given to the remote stations, and the activation pulses indicate which of the remote stations 14a – 14h are to follow the instruction. Each of the activation pulses is either a zero or a one pulse, each of which addresses are particular remote station 14a – 14h according to an addressing technique that will be described below.

The microprocessor 40 of each decoder 18 in the remote stations is arranged to detect the presence of a synchronisation pulse. It then compares the following

value of the instruction byte with a stored value, and if the two are the same, the microprocessor 40 knows that the following activation pulses are commands to particular remote stations. Each remote station is then arranged to listen all of the following pulses and to keep account of the number of pulses that have occurred. Each decoder has an address stored in the memory associated with the microprocessor 14 corresponding to the position of the pulse following the instruction byte that the decoder will take as its instruction. For example, if the decoder has an address of numeral 4, it will take the fourth activation pulse after the instruction byte as being its instruction.

- 10 In the embodiment, the instruction byte has a value greater than 128, such that the first bit in the instruction byte is a one. The instruction given by the controller 12 in the embodiment is to activate the solenoid 20 attached to each decoder on or off. For example, an activation pulse being a zero will correspond with an instruction to the remote station to switch off its solenoid 20, and an activation pulse being a one pulse corresponds with an instruction to that remote station to switch on its solenoid 20.

The second stream that the controller 12 can produce is shown in figure 4c, which is referred to as an idle stream. The idle stream comprises a synchronisation pulse followed by a series of eight idle pulses. In a similar manner to the activation pulses described in relation to figure 4b, the number of idle pulses may be set according to the number of remote stations, or a fixed number greater than the number of remote stations may be used, such as 100.

The microprocessor 40 of each decoder 18 is arranged to determine the presence of the synchronisation pulse as previously described. If the following pulse is an idle pulse, the microprocessor 14 recognises the stream as an idle stream. Each decoder is then arranged to count the number of idle pulses and upon the commencement of the idle pulse corresponding to its address, the microprocessor 40 instructs the current drawing circuit 39 to switch on and off in a pattern similar to those in the zero and one pulses. However, the current drawing circuit 39 does not generate a signal directly on to the pair of wires 16,

but rather draws power from the alternating power signal to form a communication byte. In the embodiment, the microprocessor 40 is arranged to draw power from the alternating power signal via the current drawing circuit 39 on both the positive and the negative components of the idle pulse
5 corresponding to its address.

In the embodiment, each decoder is arranged to produce a one byte status indication by drawing current in the positive and negative components of the idle pulse corresponding to its address. By signing appropriate identifiers to predetermine statuses, status information such as whether the remote station is
10 currently on or off, and whether a voltage condition exists can be communicated from each remote station to the controller 12.

The microprocessor 22 of the controller 12 recovers the status bytes from each remote station 14a – 14h according to information received from the circuit 27.

Advantageously, because the communications from the remote stations to the
15 controller 12 uses a current draw mechanism these communications do not interfere with the instructions from the controller to the remote stations. Further, even if one of the remote stations fails such that its current draw mechanism is permanently switched on, this will still not effect the communications from the remote stations to the controller 12, since the controller 12 detects sudden
20 changes in current in order to recover the communication signals, thus, the communication system is robust. Further, the communication system is also efficient with the idle stream and command streams allowing the controller 12 to receiver status information from all of the remote stations and to issue instructions to all of the remote stations in are relatively rapid manner. In
25 contrast, previous systems have relied on instructions to each individual remote station, which can take a significant amount of time when a large number of remote stations are used.

The microprocessor 22 of the controller 12 is also able to produce a third type of stream shown in figure 4d which is referred to as an individual stream. The
30 stream comprises a sync pulse followed by a command byte, followed by a two

byte address in binary coded decimal, followed by a four byte data portion and a one byte check sum. The stream also comprises a 64 idle pulses following the check sum. The address in the individual stream corresponds with an address of a decoder. The individual stream allows the controller 12 to issue instructions to a specific decoder, which allows more advanced facilities such as reprogramming a remote stations address or other parameters stored in the decoder, along with querying a particular remote station on the source of a fault or other situation. Thus, the communication system allows efficient and robust communications for the vast majority of communications with specific instructions sent to individual decoders as needed.

Decoders are able to recognise individual streams from command streams by comparing the value of the command bytes that stored in the memory associated with the microprocessor 40.

The second embodiment is of the same general form as the first embodiment. However, in the second embodiment, the decoders 18 are arranged to sink 100mA of current from the alternating power signal only during a period immediately following a rising edge or falling edge of the alternating power signal. In the embodiment, this period is approximately 0.25ms for a 400Hz alternating power signal.

Also, instead of sinking current to impose an 8-bit message on the positive and negative portions of the alternating power signal, the decoder 18 sink current to impose a single bit on each of the positive and negative portions of the alternating power signal. Thus, the controller 12 receives 2 bits of information from each decoder 18 during an idle stream. These 2 bits are interpreted as follows:

Bits	Meaning
00	Decoder offline or faulty
01	Decoder on line, output (solenoid) energised, nothing to report
10	Decoder on line, nothing to report

11	Exception – a fault or event has occurred
----	---

A decoder sink current during an idle pulse corresponding to its address in an idle stream, as described above. In the second embodiment, the decoders are also arranged to sink current during the activation pulse corresponding to its address in a command stream.

- 5 If the controller 12 detects that a remote station has a fault condition, it will then poll the remote station using the individual stream. The decoder will then respond by sinking current on the idle pulses following the instruction data in the individual stream. At 2 bits per idle pulse, an 8 bit reply will be received in 32 idle pulses.
- 10 It should be appreciated that this invention is not limited to the particular embodiment described above.

- For example, the type of modulation employed by the controller 12 and the decoders 18 may be varied without departing from the spirit of the invention. In one such variation, the decoders may sink current in a frequency-shift keying
- 15 (FSK) manner, and the controller may determine what was send according to the frequency of the current sink pulses.

Dated this fifteenth day of September 2000.

Signal Data Systems Pty Ltd
Applicant

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Patent Attorneys for the Applicant(s)

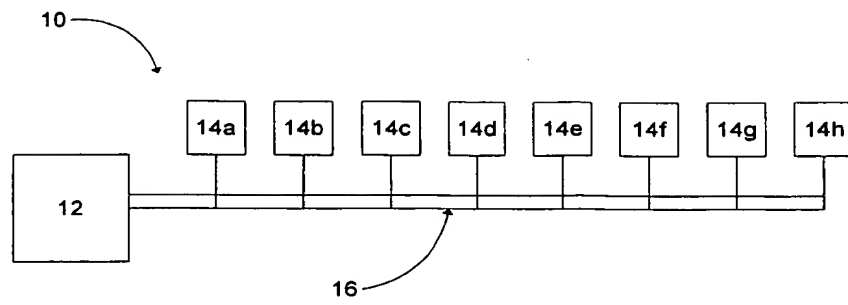


Figure 1

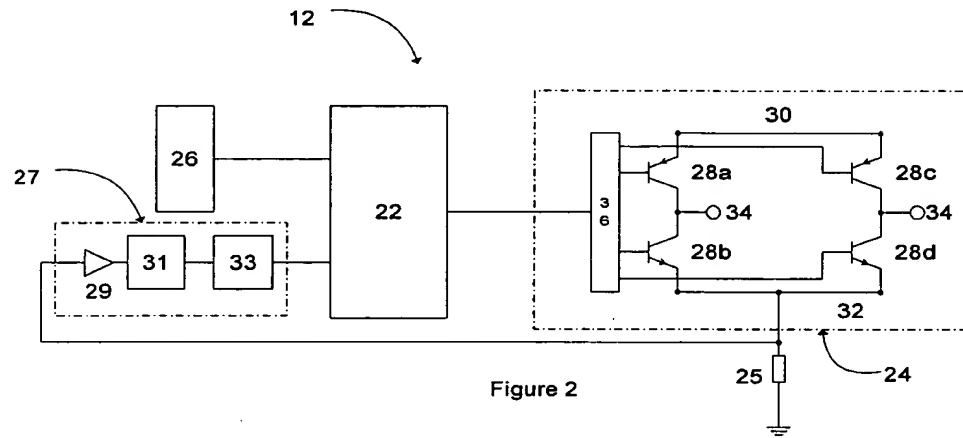


Figure 2

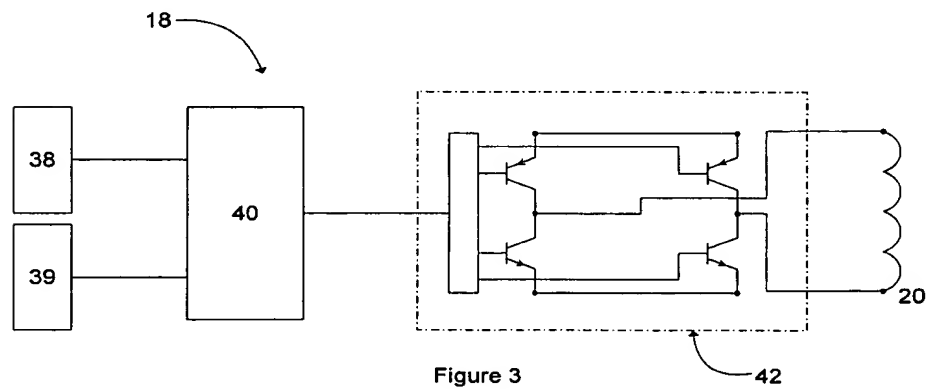


Figure 3

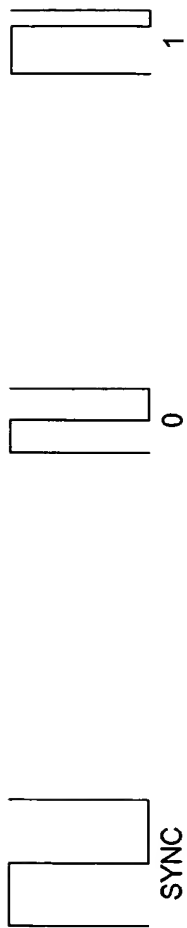


Figure 4A

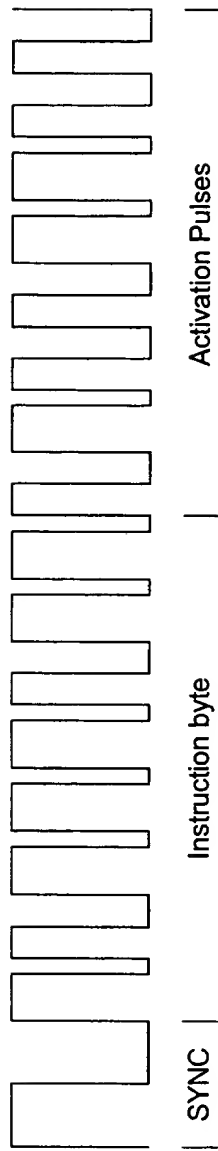


Figure 4B

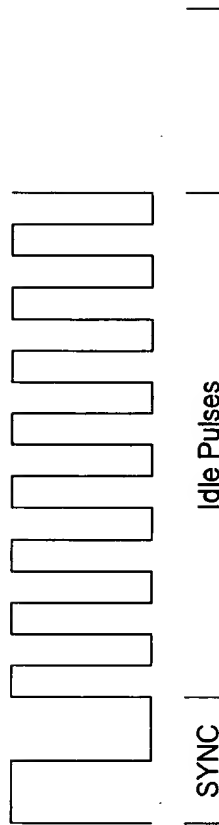


Figure 4C

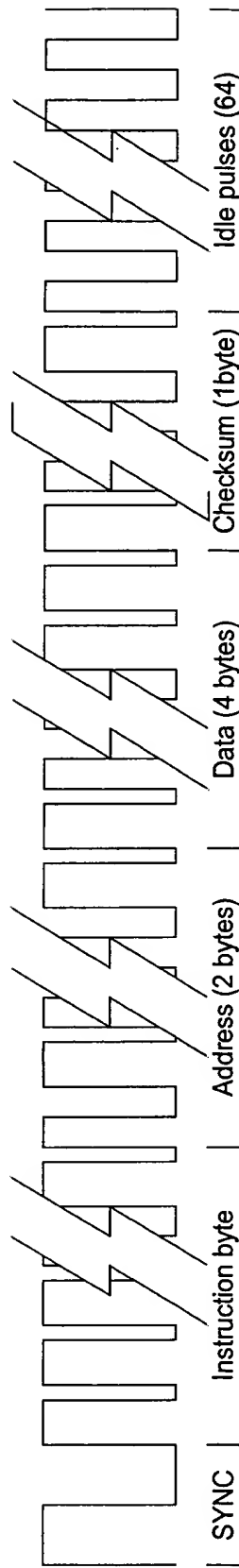


Figure 4D